R-7036-004 (10)

Using orange-fleshed sweetpotato varieties to combat vitamin A deficiency and enhance market opportunities for smallholder farmers in sub-Saharan Africa

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Abstract.

Orange-fleshed sweetpotato varieties are rich in provitamin A and can contribute significantly to vitamin A nutrition in humans. Vitamin A deficiency is common many places in sub-Saharan Africa where sweetpotato is grown. However, most sweetpotato varieties currently grown here have either white or yellow flesh and are low in provitamin A.

This paper briefly reviews recent experiences from Kenya and Uganda with respect to the identification and promotion of orange-fleshed varieties. Well-adapted orange-fleshed varieties are available and readily accepted by consumers, and can make a significant contribution to improving dietary vitamin A status, especially when provided in conjunction with information on the importance of vitamin A. As an additional incentive for their adoption, use of orange-fleshed sweetpotato as a wheat flour substitute in some snack food recipes, produces attractive and profitable products.

Consideration is given to the varietal attributes and complementary information packages that will likely be required for orange-fleshed sweetpotatoes to significantly contribute to alleviating vitamin A deficiency and to increasing opportunities for income generation over wide areas of sub-Saharan Africa.

Introduction.

Vitamin A deficiency is a serious public health problem in many developing countries, including most of the countries of eastern, central and southern Africa (WHO, 1995). It mainly affects poor, young children (6 months to six years of age) and pregnant women. The clinical form of vitamin A deficiency, xerophthalmia, results when the eye is adversely affected, and is expressed as night blindness or, at its most severe, as total, irreversible blindness. Xerophthalmia affected an estimated 3.1 million children world-wide in 1995 (IVACG, 1995). Sub-clinical vitamin A deficiency affects many more people – an estimated 227.6 million in 1995 (IVACG, 1995) – and results in increased sickness and death rates due to diseases such as diarrhea and measles among those affected.

There are two main causes of vitamin A deficiency in humans: failure to consume adequate amounts of vitamin A (or vitamin A precursors); and failure to absorb vitamin A during digestion, due to poor health caused by malaria, measles, intestinal parasites and other diseases. Absorption of vitamin A precursors can also be reduced if fat is lacking in the diet. Public health efforts aimed at combating vitamin A deficiency call for a combined approach, including supplementation (massive dose vitamin pills) for those suffering from deficiency, coupled with long-term nutritional education, dietary diversification, and food fortification (IVACG, 1995). Promoting consumption of locally available vitamin A-rich foods that can be grown in home gardens holds particular promise in many places, due to its technical feasibility and cost-effectiveness. Orange-fleshed sweetpotatoes can be a very suitable crop for this approach (Low et al. 1997; Woolfe, 1992).

Foods contain varying levels of vitamin A or its precursors, which may be absorbed by the body during digestion and used directly by the body, or following conversion to vitamin A. Animal products generally contain vitamin A, while plants contain provitamin A (vitamin A precursors), the most common of which is the carotenoid pigment, ß-carotene. Generally, orange-colored fruits and vegetables, such as papaya, mango and orange-fleshed sweetpotatoes are high in provitamin A. Green leafy vegetables are also high in provitamin A, but there is some question as to the dietary availability of provitamin A from this source (de Pee et al. 1995).

Vitamin A values of foods are measured in retinol equivalents (RE) as a means of making standard comparisons among foods. Human dietary vitamin A requirements vary with age and sex. Some recommended daily allowances (RDAs) by age and sex are as follows: 1-3 years, 400 µg RE; 4-6 years, 500 µg RE; 7-10 years, 700 µg RE; non-pregnant female over 10 years, 800 µg RE; and males over 10 years, 1000 µg RE (Williams and Worthington-Roberts, 1988). Small quantities of orange-fleshed sweetpotatoes, which may contain from 300 µg RE, to over 3,000 µg RE per 100g fresh weight, can easily provide such RDAs while also serving as a rich source of other vitamins and nutrients (Woolfe, 1992).

Sweetpotato is widely grown in eastern, central and southern Africa (to a lesser extent in West Africa), where it is prized by the region's resource-poor farmers both as a reliable, low input, food security crop, and increasingly, for its commercial potential (Minde et al. 1998). The bulk of sweetpotato production in this region is still accounted for by a large number of farmers' varieties. Over the years these varieties have been selected by farmers, based on the ability to yield storage roots of acceptable consumer quality, and to produce planting material for continued propagation.

Most African varieties have white, cream or yellow flesh (low in provitamin A), while few have orange flesh (high in provitamin A). While white- to yellow-colored sweetpotatoes have been reported to contain little or no provitamin A, orange-fleshed sweetpotatoes contain good quantities, principally of ß-carotene. There is a high correlation between color and hue values of orange-fleshed varieties , as measured using color difference meters, and their ß-carotene content (Simonne et al., 1993; Takahata et al., 1993).

The African sweetpotato varieties typically have relatively high storage root dry matter content, and are somewhat dry- or mealy-textured when cooked. This is in contrast to many sweetpotato varieties introduced from outside the region (Carey et al. 1997) and to the commercial varieties available in South Africa (Laurie et al. 1998) that typically have relatively low storage root dry matter content and are moist textured when cooked. In addition, orange-fleshed, low dry matter varieties often have a strong carrot- or squash-like flavor that is quite distinct from the 'mild' flavor typical of the African varieties.

Until recently, relatively little consideration was given to using orange-fleshed sweetpotato as a means to combat vitamin A deficiency in sub-Saharan Africa. Reasons for this may include:

a) Generally limited numbers of and support for sweetpotato improvement programs;
b) Limited awareness by root crops researchers and farmers about the extent of the vitamin A deficiency problem in Africa and of the potential of orange-fleshed sweetpotatoes to help to ameliorate the problem, combined with limited demand from public health workers for orange-fleshed sweetpotato varieties as a rich, locally adapted source of vitamin A; and
c) The perception by researchers that consumer preference for high root dry matter content and mild flavor would prevent adoption of exotic, orange-fleshed varieties, and lack of awareness of the potential for identifying orange-fleshed types with high dry matter content and mild flavor in the local germplasm or through breeding of new varieties, and;
d) The relative lack of success of earlier efforts in Asia, where moist-textured varieties developed at AVRDC were rejected by consumers (Opeña et al. 1989).

Recent experiences and findings in Kenya and Uganda have led us to reassess the potential for widely promoting orange-fleshed sweetpotatoes, not only to combat vitamin A deficiency in SSA, but also to enhance the income generating capacity of the crop through the development and promotion of new products. In this paper, we summarize information from these experiences, some of which have already been reported elsewhere.

Materials and Methods.

Provitamin A content of selected sweetpotato varieties in Kenya (reported in detail in K'osambo, 1998). Four sweetpotato clones – KEMB 10, TIS 2534, SPK 004 and Japones tresmesino selecto (CIP 420009) - were grown at the Kabete campus of the University of Nairobi, Kenya. The effect of plant age on the carotenoid content of four cultivars was assessed by sampling plants at 12, 16, 20 and 24 weeks after planting. At each sampling date, 3 plants were randomly selected and the largest storage root harvested from each plant. Different plants were sampled each month. Carotenoids were extracted according to the procedure of Khachik et al. (1992). Total carotenoid content was determined spectrophotometrically as described by Imungi and Potter (1983).

An action research project in southwestern Kenya. A project sponsored by the International Center for Research on Women (ICRW) was carried out by KARI, CIP and the NGO CARE at locations in South Nyanza province of Kenya, to investigate the potential to increase dietary vitamin A intake in children, through the promotion of orange-fleshed sweetpotato varieties. The rationale and methodology of this project are described in Low et al. (1997) along with initial results. Project methodology is briefly summarized here. The intervention area was chosen on the basis of surveys previously conducted by UNICEF and the Government of Kenya that indicated that vitamin A deficiency was serious in the area. It was also chosen, as sweetpotato is an important crop in the area (though orange-fleshed varieties were not grown). Prior to the initiation of the study a set of potentially promising orange-fleshed varieties to be promoted by the project had been identified from variety trials conducted by KARI and CIP (Gichuki et al. 1997)

Areas around Rongo and Ndhiwa in South Nyanza Province of Kenya were chosen for the work. In each area 10 women's groups were chosen for the study. The vitamin A nutritional status of children (from 1 to 5 years of age) of members of these groups was assessed using the Helen Keller International (1994) food frequency recall method. In Rongo, children of 88 women were assessed, and in Ndhiwa, children of 77 women were assessed. All groups in each area received orange-fleshed sweetpotato varieties for group-managed trials, while 5 groups in each area received an intervention program of training on vitamin A nutritional information, and on sweetpotato utilization, including recipes for snacks (chapatis, mandazis) and weaning foods. Following a one-year period of intervention or non-intervention, the vitamin A nutritional status of the children of group members in each area was once again assessed using food frequency recall method.

Identification and consumer acceptance of an orange-fleshed variety in Uganda. . On-farm trials of officially released Ugandan sweetpotato cultivars (Bwanjule, New Kawogo, Sowola, Tororo 3, Wagabolige and Tanzania–locally known as Osukut) and advanced clones (52, 93/29, 178, 316 and 324) from the Uganda breeding program were conducted at three sites in Gweri, and Dokolo villages near Soroti, Uganda. One of the advanced clones under assessment, 316 (NIS/91/316) has orange flesh color and has previously been reported to contain 318 µg RE per 100 g fresh weight (Low et al., 1997). Introduced clones were compared with farmers' check clones, Araka, Osukut or Opejo.

At the time of planting, farmers were given enough cuttings to plant twenty mounds for harvest with researchers, and 20 additional mounds for piecemeal harvesting at their own discretion and for maintenance of planting material. Mound spacing and other conditions varied across farms. Trials were planted on 20/6, 15/5 and 30/6/97, respectively and were harvested on 5/11/97, between 128 and 175 days after planting. At harvest, storage root yield was determined based on area harvested and farmer comments were elicited.

A consumer acceptance taste test by local farmers and consumers was performed using the sweetpotatoes produced in the first trial. Storage roots of each clone were cooked in separate pots using the local steaming/boiling technique. Samples were then placed on plates and coded to conceal the names of the clones. The consumers were asked to assess appearance and taste of each sample. Illiterate consumers were assisted to fill in evaluation forms. The sex and age of each consumer was noted, and results were evaluated separately for men, women and children, in order to see if there were differences in taste preferences among groups.

Comparative gross margins of sweetpotato and wheat products. Methods used in this study were reported by Hagenimana and Owori (1997) in their report on feasibility, acceptability and production costs of sweetpotato-based products in Uganda. A study was conducted in Lira, Uganda, to assess the feasibility and profitability of partially substituting sweetpotato cooked and mashed, or as flour, for wheat flour when making chapatis, mandazis, buns and bread. Roughly 30% of the wheat flour in recipes for these products was substituted with sweetpotato according to recipes presented in Hagenimana et al. 1998ab). Comparative gross margins per unit for the wheat and sweetpotato products were calculated.

Results and Discussion

Provitamin A content of selected sweetpotato varieties in Kenya. The provitamin A contents of storage roots of four cultivars, at four dates after planting, are presented in figure 1. Provitamin A content varied significantly among cultivars, with the orange-fleshed Japones tres mesino and SPK 004 having the highest and the white-fleshed TIS 2534 having only a trace. Yellow-fleshed KEMB 10 had relatively low levels of provitamin A. Plant age influenced provitamin A content, with the highest levels recorded for the orange-fleshed varieties at 20 weeks after planting.

To illustrate the potential of the varieties evaluated to contribute to dietary vitamin A, the amounts of sweetpotato of each variety that would be required to meet human requirements for vitamin A were calculated by age and gender group. The provitamin A contents of fresh roots of sweetpotato cultivars at 20 weeks after planting (data presented in figure 1) were used to make the calculations. The results are presented in Table 1, and clearly illustrates that relatively small amounts of orange-fleshed sweetpotato (less than 100g) can satisfy dietary vitamin A requirements for small children, while consumption of impossibly large amounts of white and yellow fleshed sweetpotatoes would be required to provide the same amounts of provitamin A. The figures for consumption requirements presented in Table 1 are only illustrative, as some losses of provitamin A due to oxidative degradation and isomerization occur during cooking. However, quantities of less than 100 g of cooked orange-fleshed sweetpotato would still be sufficient to provide required amounts for young children if losses of 25 to 30% occur during cooking, as reported by Woolfe (1992) and K'osambo et al. (1998).

An action research project in southwestern Kenya. Figure 2 presents the vitamin A nutritional status of children (1 to 5 years) of women's group members from the communities of Ndhiwa and Rongo in South Nyanza province of Kenya. Data are presented from each community for 'control' groups that received only orange-fleshed sweetpotatoes, and for 'intervention' groups that also received training on nutrition and utilization of sweetpotato. Nutritional status of children was lower in Ndhiwa than in Rongo probably due to the somewhat less favorable climatic and economic conditions in Ndhiwa. In Ndhiwa, the level was below 6 on the Helen Keller International index, confirming that vitamin A deficiency was a serious problem in the area, while in Rongo it was slightly above the critical level.

During the course of the study, the nutritional status of control groups declined in both Ndhiwa and Rongo, probably due to unfavorable climatic conditions that year.

However, the nutritional status of the 'intervention' groups in both communities either increased or remained the same during the period of study. At the end of the study the mean nutritional status of the children of 'intervention' groups was above the critical HKI score of 6, while it was below 6 for the control groups in both communities.

Table 2 presents selected information on the frequency of foods by children of control and intervention group members from each community following the study. These results indicated that, while there was an increase in consumption of orange-fleshed sweetpotato and sweetpotato leaves by children of intervention group members, consumption of other vitamin A-rich food sources, and fats played a major role in increasing the HKI scores of the intervention groups relative to control groups. These results illustrate that simply providing farmers with orange-fleshed sweetpotato varieties was not sufficient to improve vitamin A nutrition of their children. Nutritional education and information on sweetpotato utilization, combined with orange-fleshed sweetpotato varieties, resulted in a significant improvement in vitamin A nutritional status of children.

Orange-fleshed varieties promoted in Ndhiwa and Rongo included Japones tresmesino and SPK 004 mentioned in the previous section. Japones tresmesino has the low dry matter content (about 22%) and moist texture typical of the USA-type sweetpotatoes. SPK 004 has a higher dry matter content (about 28%) and drier texture typical of African sweetpotato varieties. While Japones tresmesino was not preferred by adult consumers, it was found to be very acceptable during the study, both for direct consumption by children, and when used as a boiled and mashed ingredient in fried and baked product recipes. In comparison with drier textured varieties, boiled and mashed Japones tresmesino mixes easily into recipes in which sweetpotato serves as s wheat flour substitute.

Identification and consumer acceptance of an orange-fleshed variety in Uganda. Table 3 presents results from the harvest of three on-farm trials near Soroti, Uganda, and for a taste evaluation of sweetpotatoes from one of the trials. Farmers comments on clones in two of the trials are also presented. Clone 316, the only orange-fleshed variety in the trials, was among the top yielders in each trial. Furthermore, farmers assessed it as having good commercial potential on the basis of yield and root appearance, as it would likely compete well with Osukut, the currently predominant commercial variety that has cream colored skin and yellow flesh. Taste test results are reported separately for men, women and children. Clone 316 received the highest acceptability rating by children, while Osukut received the highest ranking by men and women. It is noteworthy that clone 316 is not a moist-textured orange-fleshed type, but rather has a dry matter content of over 30% and the dry texture typical of most Ugandan sweetpotato varieties.

Assessment of clone 316 by farmers at the Soroti trial site was positive, and they are already expanding production of this clone in anticipation of a good market. It is worth noting that no conscious effort was made by the Ugandan breeding program to select orange-fleshed varieties. Orange-fleshed clones occur at a fairly high frequency in the segregating populations generated by the breeding program, but were often eliminated on the basis of anticipated poor performance with respect to dry matter content, taste and texture. Given the initial apparent success of 316, additional emphasis will be given by the Ugandan breeding program to the selection of new orange-fleshed varieties.

Comparative gross margins of sweetpotato and wheat products are presented in Table 4. For each of the products evaluated – chapatis, mandazis, buns and bread - the net revenue per unit in the market in Lira, was higher for the sweetpotato product than for the product in which wheat flour alone was used. This was principally due to the low cost of sweetpotato relative to wheat flour, and in the case of mandazis, to reduced oil absorption by the sweetpotato product.

Mandazis, chapatis and buns are popular snack foods with ready market in urban and rural settings throughout Kenya and Uganda. Their relatively low cost makes them affordable and attractive to many consumers. In the study on feasibility, acceptability and production costs of sweetpotato-based products in Lira (Hagenimana and Owori, 1997) mandazis were selling at $0.05 each, and chapatis at $0.10. A doubling of the profit on each mandazi sold, through the incoroporation of sweetpotato, can represent a significant improvement in income to a vendor of these products. This and other studies of adoption of sweetpotato-based snack products in Kenya (Owuor, 1996) and Uganda (Jabati, 1995) have shown ready adoption of recipes by entrepreneurs and households, but also revealed that careful attention to recipes and business practices is required to ensure profitability.

While it is not essential to use orange-fleshed sweetpotatoes to make sweetpotato snack products, their use imparts an attractive orange color to the products, leading to higher consumer acceptance of the sweetpotato-based product than the wheat product.

Conclusions

Recent experiences in Kenya and Uganda have indicated that there is good potential for widespread consumer acceptance of orange-fleshed sweetpotato varieties, for fresh consumption and marketing, and for incorporation into snack products such as mandazis and chapatis. This represents a large opportunity for sweetpotato research and development programs in sub-Saharan Africa as varieties grown in the region at this time are predominantly white-, or light yellow-fleshed. Varieties for fresh consumption and marketing would preferably have the high dry matter content and dry texture upon cooking preferred by adult consumers. However, moist-textured, orange-fleshed varieties also find ready acceptance as boiled and mashed components in mandazi and chapati recipes, and as food for small children.

Promising varieties of both high and low dry matter quality types adapted to African production conditions have already been identified and some are available for international distribution and testing. However there is a need for continued breeding and selection, particularly of high dry matter, orange-fleshed types, as these are relatively rare. Also, while many introduced low dry matter orange-fleshed varieties are available, their generally low foliage vigor in comparison with most African varieties, and their general lack of resistance to sweetpotato virus disease will render them unsuitable in some environments (Carey et al. 1997).

Given their high provitamin A content, low input requirements and adaptation to African farming systems, orange-fleshed sweetpotatoes can make a sustainable contribution to human vitamin A nutrition. However, vitamin A deficiency is a public health issue, and root crops researchers should not be under the illusion that they can make a significant impact at alleviating this problem simply by focusing on variety development and dissemination. As seen during the study in Kenya, vitamin A nutritional status only improved in groups which received nutritional education. Efforts focusing on combating vitamin A deficiency should always involve people with relevant competence from the public health sector.

Promotion of orange-fleshed varieties for their food security and nutritional value and for their income generating potential does appear to be an attractive venture for national extension and NGOs many places in sub-Saharan Africa. Simple educational materials providing information on recipes and varieties (Anon. 1997ab) can assist to disseminate the message.

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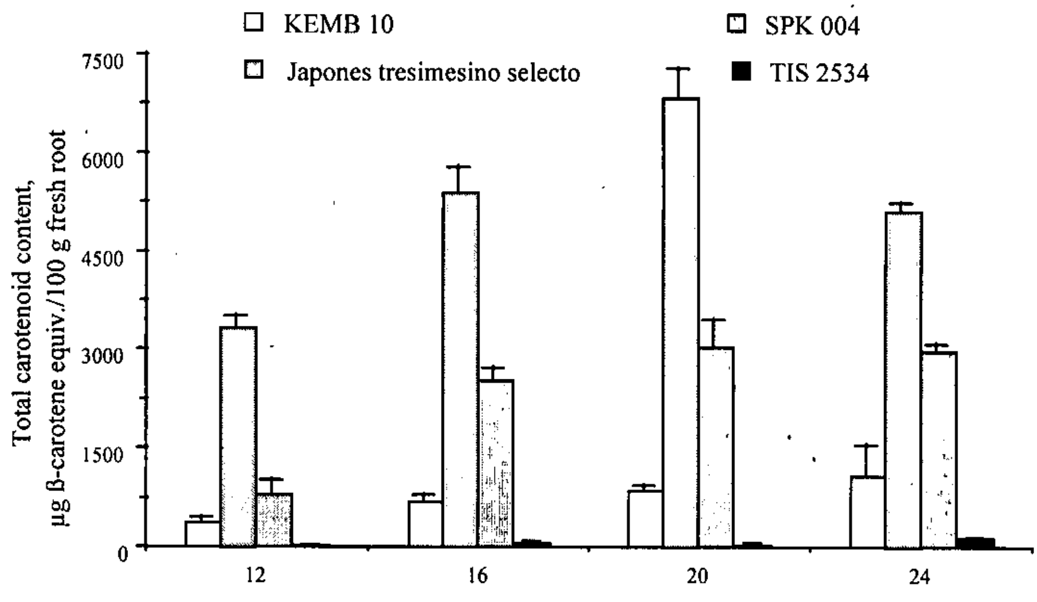

Figure 1. Total carotenoid content of storage roots of 4 sweetpotato cultivars at different plant ages.

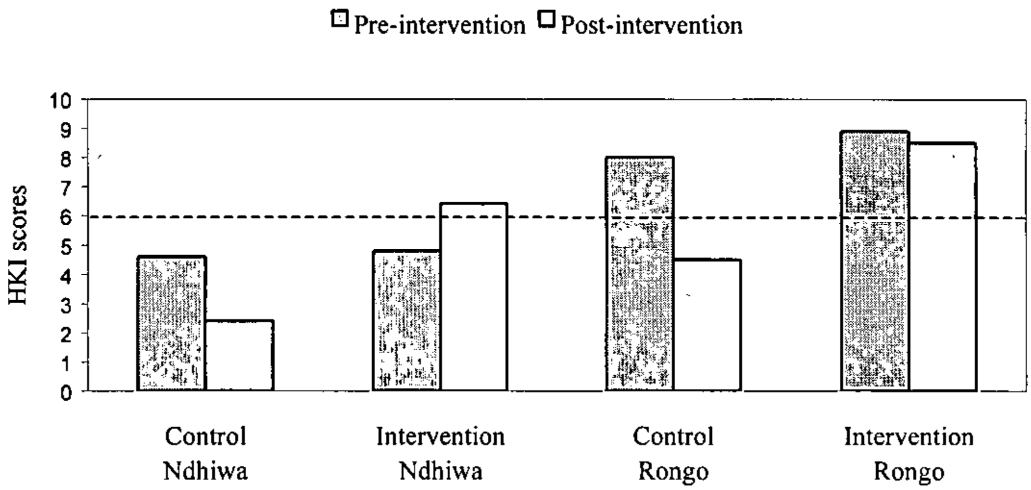

Figure 2. Vitamin A nutritional status, measured by the Helen Keller International (HKI)
food frequency method, or children of women's group members in Ndhiwa and Rongo Kenya. All groups received planting materials of orange-fleshed sweetpotato varieties. Intervention groups received information on nutrition and sweetpotato utlization. HKI

Table 1. Amounts of fresh storage roots (in grams) of four sweetpotato varieties grown in Kenya that would be required to supply recommended daily allowances of vitamin A to different human age and gender groups. Amounts are derived from total carotenoid concentrations at 20 weeks after planting, of the varieties presented in Table 1.

Human age or gender group and daily vitamin A requirement (μg retinol equivalent)	Sweetpotato variety and provitamin A content (μg retinol equivalent per 100 g fresh weight)			
	TIS 2534 (11)	KEMB 10 (151)	SPK004 (515)	Japones (1152)
1 to 3 years (400)	3,636	265	78	35
4 to 6 years (500)	4,545	331	97	43
7 to 10 years (700)	6,364	463	136	61
Females over 10 years (800)	7,273	530	155	69
Males over 10 years (1,000)	9,091	662	194	87

Table 2. Mean frequency (days/week) of consumption of some foods by children (1 to 5 years of age) of members of women's groups in Rongo and Ndhiwa, Kenya following a period of nutrition education and promotion of orange-fleshed sweetpotato.

	Rongo groups		Ndhiwa groups	
Food	Control	Intervention	Control	Intervention
Maize	5.73	5.36	5.69	4.56
Orange sweetpotato	0.46	2.38	0.83	2.59
White sweetpotato	1.00	0.69	0.53	1.00
Dark green leafy vegetables	4.66	5.29	1.53	3.54
Sweetpotato leaves	0.02	0.73	0.50	1.24
Mango	1.95	2.16	0.00	1.27
Ripe papaya	2.41	2.60	0.58	0.63
Liver	0.22	1.31	0.56	0.80
Omena (small fish) soup	1.05	1.51	1.61	1.22
Food cooked with oil	1.93	3.44	1.22	1.46
Egg yolk	1.59	3.00	0.97	1.98
Butter/ghee	0.20	0.47	0.00	1.59
Cow milk	3.44	4.20	5.17	2.88

Table 3. Yield, taste evaluation and farmers' comments on sweetpotato varieties tested in on-farm trials in Gweri and Dokolo villages near Soroti, Uganda (October, 1997).

Clone	Storage roots by farm (t/ha) 1	2	3	Taste evaluation by[z] Men (n=7)	Women (n=7)	Children (n=5)	Flesh color	Comments by farmers
52	25.1	4.8	5.1	3.1	3.1	3.0	Yellow	1. Rats prefer. 2. Drought tolerant
Araka[y]	23.7	-	5.9	3.0	3.3	4.0	White	1. Not marketable. Good for dried storage
316	22.7	7.9	5.2	3.4	3.9	4.6	Orange	1. Best experimental clone. Quick cooking. 2. Best test clone. Cream skin color = commercial potential
Sowola	21.3	4.3	4.4	4.1	2.9	3.0	Cream	1. Earliest. High yielding 2. Poor establishment.
178	17.5	6.5	2.0	3.3	2.8	3.8	White	1. Rats pefer due to poor cover. 2. Fair yield, would try again
Wagabolige	17.4	6.7	4.3	2.9	3.1	2.6	Cream	1. Not drought tolerant 2. Good taste, good yield
Tororo 3	16.7	2.1	1.7	2.1	3.9	3.8	Cream	1. Not drought tolerant 2. Discard.
Osukut[y]	10.5	5.7	5.7	4.6	4.6	3.6	Yellow	1. Major commercial variety gave rather poor yield. 2. Marketable; good taste; rots.
324	8.5	0.6	1.9	2.3	3.7	3.8	Cream	2. Discard
93/29	8.2	5.4	4.8	2.8	2.0	2.2		2. Fair yield; red skin color = no commercial potential
New Kawogo	8.0	0	0.3	3.8	3.1	3.4	Cream	1. Low yield. Root placement outside mound bad 2. Discard.
Bwanjule	5.7	2.7	1.4	3.3	2.6	3.4	White	1. Low yield, good vines 2. Discard
Opejo[y]	-	11.1	-	-	-	-		2. Good taste. Marketable. Good in-ground storability. Not drought tolerant. Requires low soil fertility
Mean	15.4	4.8	3.6					

[z] Taste assessment scale: 1 = very poor, 2 = poor, 3 = fair; 4 = good; 5 = very good

[y] Farmers' varieties. Osukut is officially released in Uganda as 'Tanzania'

Table 4. Comparative gross margins of sweetpotato and wheat flour products, Lira, Uganda

	Net revenue per unit of product (US$)		
Product	Wheat flour	Cooked and mashed sweetpotato	Sweetpotato flour
Chapati	0.032	0.045	0.047
Mandazi	0.014	0.023	0.023
Bun	0.007	0.014	0.015
Bread (500g loaf)	0.058	0.065	0.069